Exploration of Tooth Growth Data

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Overview

I will first load and explore the data, before summarizing it briefly. Then I will compare the tooth growth between different dosages of different supplements delivery methods, to see if there is any statistically significant impact, at the 5% level.

Dataset & Initial Exploration

Loading the dataset

```
library(ggplot2)
library(datasets)
library(gridExtra)
```

```
# What is the structure?
str(ToothGrowth)
```

```
## 'data.frame':    60 obs. of  3 variables:
##  $ len : num  4.2 11.5 7.3 5.8 6.4 10 11.2 11.2 5.2 7 ...
##  $ supp: Factor w/ 2 levels "OJ","VC": 2 2 2 2 2 2 2 2 2 2 ...
##  $ dose: num  0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 ...
```

```
# Summary
summary(ToothGrowth)
```

```
##       len        supp         dose      
##  Min.   : 4.20   OJ:30   Min.   :0.500  
##  1st Qu.:13.07   VC:30   1st Qu.:0.500  
##  Median :19.25           Median :1.000  
##  Mean   :18.81           Mean   :1.167  
##  3rd Qu.:25.27           3rd Qu.:2.000  
##  Max.   :33.90           Max.   :2.000
```

```
# Slight conversion needed for dosage (as a factor)
tooth_data <- ToothGrowth
tooth_data$dose <- as.factor(tooth_data$dose)
```

Graphical Exploration

Now I'm going to explore and plot the data a bit more thoroughly. There are only 2 main characteristics to this data, dosage given (dose) of the supplement (supp).

Note, the main code for this is suppressed, simply to keep the report length down. All code is present in the underlying RMarkdown file, which can be found by going to the github repository linked in the appendix.

```
grid.arrange(plot1, plot2, plot3, ncol = 3)
```

So just based on a graphical analysis, I expect to see statistical significance:

- between dosages (independent of supplement delivery method)
- between supplement delivery method, independent of dosages
- between supplement delivery method at lower dosages

Figure 1: Boxplots comparing dosage, supplement delivery method, and the combination of the two, from left to right.

Statistical Significance Between Dosages

I will compare the distributions between dosages:

- 0.5 mg/day vs 1.0 mg/day
- 0.5 mg/day vs 2.0 mg/day
- 1.0 mg/day vs 2.0 mg/day

```
test_0_5_v_1 <- t.test(len ~ dose, tooth_data[tooth_data$dose != 2, ],
                       paired = FALSE, var.equal = FALSE)
test_0_5_v_2 <- t.test(len ~ dose, tooth_data[tooth_data$dose != 1, ],
                       paired = FALSE, var.equal = FALSE)
test_1_v_2 <- t.test(len ~ dose, tooth_data[tooth_data$dose != 0.5, ],
                     paired = FALSE, var.equal = FALSE)

dosage_table <- data.frame("comparison" = c("0.5 mg/day vs 1.0 mg/day",
                                            "0.5 mg/day vs 2.0 mg/day",
                                            "1.0 mg/day vs 2.0 mg/day"),
                           "p-value" = c(round(test_0_5_v_1$p.value, 4),
                                         round(test_0_5_v_2$p.value, 4),
                                         round(test_1_v_2$p.value, 4)))
names(dosage_table) <- c("comparison", "p-value")

dosage_table
```

```
##                 comparison p-value
## 1 0.5 mg/day vs 1.0 mg/day       0
## 2 0.5 mg/day vs 2.0 mg/day       0
## 3 1.0 mg/day vs 2.0 mg/day       0
```

So, as expected, the difference between tooth growth length is significant by dosage, in all cases, with increasing dosage seeing increasing tooth growth.

I checked power in the appendix, its reasonably high (at least 96.6%) in all possible cases, reducing the risk of a type II error.

Statistical Significance Between Supplement Delivery Method

I will compare the distributions between supplements:

- OJ vs VC (orange juice vs ascorbic acid)

```
test_OJ_v_VC <- t.test(len ~ supp, tooth_data, paired = FALSE, var.equal = FALSE)

supplement_table <- data.frame("comparison" = "OJ vs VC",
                               "p-value" = round(test_OJ_v_VC$p.value, 4))
names(supplement_table) <- c("comparison", "p-value")

supplement_table
```

```
##   comparison p-value
## 1   OJ vs VC  0.0606
```

So, the difference between supplements, independent of dosage, is not statistically significant, in terms of tooth growth, at the 5% level. In addition, the power is very low (see appendix for calculation), at only 45.3%

Statistical Significance Between Supplement Delivery Methods, Considering Dosage

I show this work in the appendix, to keep the length of the report down, and because the power is low in all variations here (always less than 82%).

The difference in tooth growth, between supplement delivery methods, when considering dosage, is statistically significant only for 0.5 mg/day and 1.0 mg/day dosage.

The power for the 0.5 mg/day calculation is not large, at only 69.4%, so the result is suspect (possible type II error) (see appendix for power calculations).

The power for the 1.0 mg/day comparison is higher, at ~81.05%, so the chances of a type II error are lower in that case, but more samples would be better.

Conclusions (and Assumptions)

Assumptions

- The guinea pig data is not paired, between supplement delivery methods or doses
- The variance between sample sets is not expected to be equal
- The populations are otherwise independent
- Proper sampling methodologies were used, so that other factors were controlled
- A proper double-blind study was done, so those researchers measuring the tooth length were not biased
- 60 guinea pigs is enough to reduce power issues (see appendix for analysis)

Conclusions

- Higher dosages make teeth grow more, independent of supplement delivery methods
- Orange Juice (OJ) makes teeth grow more than ascorbic acid (VC) at 1.0 mg/day, but no real difference occurs at 2.0 mg/day, and we cannot be confident of avoiding a type II error at 0.5 mg/day.

Appendices

Statistical Significance Between Supplement Delivery Methods, Considering Dosage

I will compare the distributions between supplement delivery methods, considering dosage:

- OJ vs VC, for 0.5 mg/day
- OJ vs VC, for 1.0 mg/day
- OJ vs VC, for 2.0 mg/day

```
test_OJ_v_VC_0_5 <- t.test(len ~ supp, tooth_data[tooth_data$dose == 0.5, ],
                           paired = FALSE, var.equal = FALSE)
test_OJ_v_VC_1 <- t.test(len ~ supp, tooth_data[tooth_data$dose == 1, ],
                         paired = FALSE, var.equal = FALSE)
test_OJ_v_VC_2 <- t.test(len ~ supp, tooth_data[tooth_data$dose == 2, ],
                         paired = FALSE, var.equal = FALSE)

mixed_table <- data.frame("comparison" = c("OJ vs VC, 0.5 mg/day",
                                           "OJ vs VC, 1.0 mg/day",
                                           "OJ vs VC, 2.0 mg/day"),
                          "p-value" = c(round(test_OJ_v_VC_0_5$p.value, 4),
                                        round(test_OJ_v_VC_1$p.value, 4),
                                        round(test_OJ_v_VC_2$p.value, 4)))
names(mixed_table) <- c("comparison", "p-value")

mixed_table
```

```
##             comparison p-value
## 1 OJ vs VC, 0.5 mg/day  0.0064
## 2 OJ vs VC, 1.0 mg/day  0.0010
## 3 OJ vs VC, 2.0 mg/day  0.9639
```

Sample Size (Power)

0.5 mg/day vs 1.0 mg/day, independent of supplement delivery method

```
d_delta <- mean(tooth_data$len[tooth_data$dose == 1]) -
           mean(tooth_data$len[tooth_data$dose == 0.5])
d_type <- "two.sample"
d_sd <- sd(tooth_data$len[tooth_data$dose != 2])
d_siglevel <- 0.05
d_n <- 20
power.t.test(delta = d_delta, sd = d_sd, sig.level = d_siglevel, type = d_type, n = d_n)$power
```

```
## [1] 0.9927903
```

0.5 mg/day vs 2.0 mg/day, independent of supplement delivery method

```
d_delta <- mean(tooth_data$len[tooth_data$dose == 2]) -
           mean(tooth_data$len[tooth_data$dose == 0.5])
d_sd <- sd(tooth_data$len[tooth_data$dose != 1])
power.t.test(delta = d_delta, sd = d_sd, sig.level = d_siglevel, type = d_type, n = d_n)$power
```

```
## [1] 0.9996991
```

1.0 mg/day vs 2.0 mg/day, independent of supplement delivery method

```
d_delta <- mean(tooth_data$len[tooth_data$dose == 2]) -
           mean(tooth_data$len[tooth_data$dose == 1])
d_sd <- sd(tooth_data$len[tooth_data$dose != 0.5])
power.t.test(delta = d_delta, sd = d_sd, sig.level = d_siglevel, type = d_type, n = d_n)$power
```

```
## [1] 0.9660945
```

OJ vs VC, independent of dosage

```
d_delta <- mean(tooth_data$len[tooth_data$supp == "OJ"]) -
           mean(tooth_data$len[tooth_data$supp == "VC"])
d_sd <- sd(tooth_data$len)
d_n <- 30
power.t.test(delta = d_delta, sd = d_sd, sig.level = d_siglevel, type = d_type, n = d_n)$power
```

```
## [1] 0.4531795
```

OJ vs VC, 0.5 mg/day

```
d_delta <- mean(tooth_data$len[tooth_data$supp == "OJ" & tooth_data$dose == 0.5]) -
           mean(tooth_data$len[tooth_data$supp == "VC" & tooth_data$dose == 0.5])
d_sd <- sd(tooth_data$len[tooth_data$dose == 0.5])
d_n <- 10
power.t.test(delta = d_delta, sd = d_sd, sig.level = d_siglevel, type = d_type, n = d_n)$power
```

```
## [1] 0.6942405
```

OJ vs VC, 1.0 mg/day

```
d_delta <- mean(tooth_data$len[tooth_data$supp == "OJ" & tooth_data$dose == 1]) -
           mean(tooth_data$len[tooth_data$supp == "VC" & tooth_data$dose == 1])
d_sd <- sd(tooth_data$len[tooth_data$dose == 1])
power.t.test(delta = d_delta, sd = d_sd, sig.level = d_siglevel, type = d_type, n = d_n)$power
```

```
## [1] 0.8104925
```

OJ vs VC, 2.0 mg/day

```
d_delta <- mean(tooth_data$len[tooth_data$supp == "OJ" & tooth_data$dose == 2]) -
           mean(tooth_data$len[tooth_data$supp == "VC" & tooth_data$dose == 2])
d_sd <- sd(tooth_data$len[tooth_data$dose == 2])
power.t.test(delta = d_delta, sd = d_sd, sig.level = d_siglevel, type = d_type, n = d_n)$power
```

```
## [1] 0.02774515
```

Additional Resources

- Github Repository

Session Information

- 3.20 GHz Intel i5 650
- 8GB RAM
- RStudio Version 0.99.902

```r
sessionInfo()
```

```
## R version 3.3.0 (2016-05-03)
## Platform: x86_64-w64-mingw32/x64 (64-bit)
## Running under: Windows 10 x64 (build 10586)
##
## locale:
## [1] LC_COLLATE=English_United States.1252
## [2] LC_CTYPE=English_United States.1252
## [3] LC_MONETARY=English_United States.1252
## [4] LC_NUMERIC=C
## [5] LC_TIME=English_United States.1252
##
## attached base packages:
## [1] stats     graphics  grDevices utils     datasets  methods   base
##
## other attached packages:
## [1] gridExtra_2.2.1 ggplot2_2.1.0
##
## loaded via a namespace (and not attached):
##  [1] Rcpp_0.12.5        digest_0.6.9       plyr_1.8.4
##  [4] grid_3.3.0         gtable_0.2.0       formatR_1.4
##  [7] magrittr_1.5       evaluate_0.9       scales_0.4.0
## [10] stringi_1.1.1      rmarkdown_0.9.6    labeling_0.3
## [13] RColorBrewer_1.1-2 tools_3.3.0        stringr_1.0.0
## [16] munsell_0.4.3      yaml_2.1.13        colorspace_1.2-6
## [19] htmltools_0.3.5    knitr_1.13
```